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(54) CABLE TERMINATION FOR USE IN GROUNDED SURFACE DISTRIBUTION APPARATUS

(71) We, JOSLYN MFG. AND SUPPLY Co., a Corporation organized under the laws of the State of Illinois, United States of America, of 155 North Wacker Drive, Chicago, Illinois, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a new and improved grounded-surface distribution apparatus and system for underground installation such as required in loop and radial underground distribution systems. More particularly, there is provided unique cable-termination load-break switch elements which make possible hot-stick disconnecting, switching, sectionalizing and the like without moving the cable or the cable terminals and providing visible separation between grounded-surface circuit elements.

The present strong trend toward underground distribution of electricity brings with it the need for new kinds of associated apparatus to provide the necessary system functions including switches, fuses surge arrestors, cable terminals, taps and joints. The new aspect of such apparatus is that it must be able to carry on its function underground in contact with and at times under water. This means that every part of the circuit which is maintained at system potential must be surrounded by a continuous sheath of impervious, void-free insulation within a continuous conductive grounded housing.

Commercial apparatus attempting to fulfill these difficult requirements is still in the early stages of development. Prior known apparatus have not been entirely successful. In fact, the trend towards such underground distribution systems is so new that standard nomenclature has not been established by the electrical industry. The term "submersible" is sometimes applied to these devices for want of a more appropriate term. "Grounded-surface distribution apparatus" is a more appropriate and more truly descriptive term for this class of equipment since a conductive grounded-outside surface is a function requirement for operational and safety reasons.

The essential and main ingredient in underground distribution of electricity is obviously cable which must carry distribution current and voltage underground with trouble-free long life performance. Recent developments in synthetic dielectric materials have made possible the production of solid polymer insulated cable with high performance and low cost. However, the advantages of the new cable cannot be realized fully without effective, safe and convenient means for connecting the cable to various devices required in underground distribution systems. By employing voltage grading and interfacial sealing techniques, it has been possible to provide grounded-surface submersible devices to perform functions of cable joining and terminating, load-breaking switching, sectionalizing, and fusing.

The term "grounded-surface" may be taken literally in that apparatus in this category does in fact have a grounded external surface preferably of metal thick enough to provide mechanical support and to carry fault current if it occurs. Conductive plastic coatings will perform part of the function of grounding the surface but they may not provide safety under fault conditions.

The difficult design problem in grounded-surface distribution apparatus is to put the

[*Price 25p*]

entire high potential circuit inside the grounded housings and still provide means for carrying out switching and sealing-off functions.

In accordance with the present invention there is provided a control unit for high voltage electric power cable terminations of the type having first and second cable terminations with respective end surfaces, the unit comprising a conductive housing releasably positioned between the respective end surfaces of the first and second terminations, insulated electrically conductive means and a current limiting fuse in the housing, means for electrically connecting respective conductor terminals within the cable terminations to the conductive means whereby a current carrying circuit is completed between the terminals through the fuse, and means for forming water-tight uniform seals between the ends of the housing and the respective terminations when the current carrying circuit is completed, the current limiting fuse providing for the interruption of the current carrying circuit between the terminals.

The invention will now be described by way of example with reference to the accompanying drawings wherein:—

Fig. 1 is a isometric view of a cable termination with a grounding cap in place,

Fig. 2 is a cross sectional view of the cable terminal of Fig. 1, and illustrating the electrical coupling components within the cable termination,

FIG. 3 is a cross sectional view of the cable termination of FIG. 1, taken along line 3—3 of FIG. 2, and illustrating the plug-in connector components within the cable termination;

FIG. 4 is a cross sectional view of the connector coupling components of FIG. 3, illustrated to a larger scale;

FIG. 5 is an exploded view of the coupling components of FIGS. 3 and 4;

FIG. 6 is an isometric drawing illustrating a grounded-surface load-break switch employing two standard load-break cable terminals and a standard "U" coupler.

FIG. 7 is a cross sectional view of a "U" coupling unit taken along line 7—7 of FIG. 6;

FIG. 8 is a cross sectional view of the "U" coupling unit of FIG. 7, taken along line 8—8 of FIG. 7, assuming that FIG. 7 illustrates the entire structure;

FIG. 9 is a top view of a single tap arrangement employing three load-break cable terminals, and a tap manifold or bus;

FIG. 10 is an elevational view of the structure of FIG. 9 and further illustrating "U" couplers in phantom;

FIG. 11 is an elevational view of a three-point manifold or bus of the type illustrated in FIGS. 9 and 10, illustrated in broken away section;

FIG. 12 is an elevational view of a surge protector for use with a cable termination and illustrated partially in broken away section;

FIG. 13 is a top view of the surge protector of FIG. 12;

FIG. 14 is a cross sectional view of a current limiting fuse for use with cable terminations;

FIG. 15 is an alternative structure of a fuse connector for use with cable terminations and illustrating a removable fuse arrangement;

FIG. 16 is an end view of the fuse structure of FIG. 15;

FIGS. 17 and 18 illustrate an alternate control center arrangement including a connecting unit having multilevel terminations to provide desired economy of space and apparatus;

FIGS. 19 and 20 illustrate the isolating or grounding of one of the lines in the control center of FIG. 17;

FIG. 21 illustrates in cross section a primary cable termination for a grounded surface submersible system;

FIG. 22 illustrates in broken away section a cable joint;

FIG. 23 is an end or bottom view of the cable joint of FIG. 22 taken along line 23—23 of FIG. 22;

FIG. 24 is a cross sectional view of the cable joint of FIG. 22, taken along line 24—24 of FIG. 22;

FIGS. 25 and 26 illustrate a switching point assembly employing an improved "T" termination; and

FIG. 27 illustrates a sub-surface switching point assembly.

Referring now to the drawings and particularly to the embodiment of FIGS. 1, 2 and 3, there is shown the details of a cable termination 30 with a grounded cover or coupling element 32 latched in sealed position. The cable termination 30 includes a conducting housing 34 of suitable material such as stainless steel, and cylindrical in cross section. A cover 35 also of conducting material such as stainless steel engages two side pins 36 in the housing 34 in a spiral bayonet action to compress an inner thrust spring 37 to be compressed in the latched position as shown so as to exert an axial thrust on a soft elastomer dielectric filler 38 confined at its lower end by a piston-like cup retainer 39.

The soft dielecric filler 38 is cast within the housing 34 to interfit with a hard dielectric filler 40 which is firmly cast and locked into the housing 34 but which projects from the other end of the housing to provide a standardized conical sealing surface 41 having a connector entrance 42. Although the hard dielectric filler 40 is illustrated as formed

of two parts $40a$ and $40b$, it may be made of one piece if desired.

As used herein, the soft dielectric filler may be of any void-free dielectric soft enough to conform to the adjacent surfaces in void-free interfacial engagement under the loading of the selected thrust spring. It has been found that a soft poly-urethane or other limited cross linked polymer, preferably castable, with a Shore A hardness of 20 to 40, works satisfactorily. As used herein, the hard dielectric filler may be of any void-free dielectric hard enough to provide mechanical strength to position the components. Castable synthetic polymers such as epoxy resins having a Shore A of 100 or higher were found satisfactory.

The soft dielectric filler 38 is designed to receive a power cable 45 of the type having a basic insulation 46 and a sheath 47. In addition to the sheath 47, the cable 45 may contain a plurality of strands of grounding wire 48. The end thrust spring 37 permits a reasonable range in diameter variation and still maintains a permanent void-free interfacial seal between the insulation 46 and the soft elastomer 38 even under submerged conditions.

The cable termination 30 includes a connector 50 for terminating the end of the cable 45 and defining a cable connector $50a$ at one end. The cable connector $50a$ has an elongated body of conducting material, such as copper and the like, and defines a receptacle 51. A conducting pin or plug 52 is adapted for insertion into an elongated axially aligned pin cavity 53, which may be part of a through bore in connector 50 or a blind bore, of the receptacle 51 to establish a low resistance connection capable of carrying rated current as well as momentary high currents. The pin 52 is connected to the short exposed end $45a$, FIG. 2, of the cable 45, and the pin 52 is formed with an elongated axially aligned socket 54 extending inwardly from the lower end of the connector. After the central conductcir $45a$ is inserted into the socket 54, a compression tool or the like is used to compress the walls of the socket inwardly into tight engagement with conductor $45a$ and thus firmly secure and electrically connect the pin 52 to the upper end of the cable 45. The pin 52 includes a cylindrical pin portion 55 (Figure 5) of reduced diameter adapted to be inserted into the pin cavity 53 of the receptacle 51 to establish electrical connection therewith.

The receptacles 51 around the pin cavity 53 thereof is square or polygonal in cross section, FIGS. 3 and 4, and includes a plurality of planar outer faces 58 which angularly intersect one another, forming a plurality of longitudinally extending parallel upper ridges 59 (Figure 5). Preferably, the ridges are provided with narrow, flattened upper faces $59a$, FIG. 4, which are tangential to a circle having its center on the longitudinal center axis of the receptacle 51. Each planar face 58 of the receptacle 51 is bisected by a longitudinally extending slot 60 extending upwardly from the lower end of the conductor and terminated adjacent the inner end of the pin cavity 53. The slots 60 bisect the faces 58 into pairs of segments of approximately equal area, and thereby form a plurality of movable fingers 62, each including one of the ridges 59 and a pair of segments on its outer surface and a curved segmented, cylindrical interface forming a wall portion of the pin cavity 53. The free ends of the fingers 62 are movable inwardly and outwardly with respect to the longitudinal central axis of the receptacle 51 and form the lower end portion thereof surrounding the pin cavity 53.

In order to establish a relatively high contact pressure between the fingers 62 and the pin 52 and thereby further reduce the resistance of the connection and increase the current carrying capacity thereof, the fingers 62 are biased inwardly by a circular tension ring 63 which is slipped over the body of the receptacle 51 and bears against the flattened surfaces $59a$ on the ridges 59. Preferably, the ring 63 is formed of a thin band of high strength material, such as beryllium-copper alloy and is dimensioned so that the inner diameter of the ring is slightly less than the distance between the flattened surfaces on the ridges 59 on the diametrically opposite fingers. Accordingly, the ring 63 is under tension and is force fitted over the lower end of the body and moved upwardly thereon toward the blind end of the pin cavity 53.

The amount of inwardly biasing force exerted on the fingers 62 by the ring 63 is selectively adjustable by movement of the ring 63 around the fingers of the receptacles 51. For example, the fingers 62 are more easily deflected near the outer or free ends, and when a ring of given internal diameter is positioned adjacent the free end, the fingers 62 have less inward deflection of the free ends than when the ring 63 is moved upward toward the blind or inner end of the pin cavity 53. The flattened surfaces of the ridges 59 permit easier movement of the ring 63 thereon without gouging of the ridges.

From the foregoing, it should be noted that the cable connector $50a$ provides a large contact surface between the connecting members thereof and additionally provides for an adjustable contact pressure over the large contact surface. It is not necessary to tighten any bolts or clamps for assembling the cable connector once the connecting members are engaged since ample holding force is achieved by the contact pressure between the connecting members. While the receptacle 51 is illustrated as having a square cross section, it is

to be understood that other configurations, such as triangular, etc., could be used instead. The fingers 62 are constructed to have a cross section that is symmetrical on opposite sides of longitudinally bisecting planes extending between the ridges 59 and the longitudinal axis of the cable connector 50. Accordingly, the inward force applied by the ring 63 to the flattened ridge surfaces is distributed fairly uniformly on both sides of the bisecting plane to the inner contact surface of the fingers 62.

The upper end of the tubular housing 34 carries a conical skirt 65, FIG. 2, so that a pair of spring latches 66 carried on the grounding cover 32 can engage with the conical skirt 65 in any radial direction. The spring latches 66 include latch loops 67 designed to be engaged by standard hot line tools for latching or unlatching the various devices which carry the standardized mating surfaces and latching elements. Suitable latch springs 68 maintain the spring latches 66 in tight assembled relation on the skirt 65.

The connector 50 also includes a switch connector 50*b* for interrupting a circuit under load. The switch connector 50*b* includes the same components as the cable connector 50*a* but additionally has arc-extinguishing components. Specifically, the switch connector 50*b* includes a switch receptacle 51*a* defining a switch cavity 53*a* formed by fingers 62. A tension ring 63 affords inward pressure to the fingers 62 in like manner as in the cable connector 50*a*. The switch connector 50*b* will accommodate a coupling conductor or switch member to provide an excellent electrical connection.

To provide for load-break features, the upper connector opening carries a liner 72 of arc-extinguishing material which co-functions with a follower 73 of arc-extinguishing material within the switch cavity 53*a* of the switch rectpacle 51*a* and which is backed up by a projection spring 74 to provide load-break effects when an associated coupling conductor is removed from the switch receptacle. The material of the liner 72 and follower 73 possesses desired arc-quenching properties and may be of synthetic polymer material carrying a suitable amount of arc-quenching material such as molybdenum sulfide or alumina.

In operation the follower 73 moves into the opening in the liner 72 when a coupling conductor 77 of the grounding cover 32 is removed from the associated switch cavity 53*a*. The cooperation of the arc-quenching elements 72 and 73 extinguishes any arc that may be formed as the coupling conductor 77 leaves the end of the switch connector 50 by de-ionization of the plasma. Since the arc is interrupted in the narrow space between the follower 73 and the liner 72 and since the follower 73 remains in the opening, there is no significant amount of ionized gas between the separated circuit elements. That is, the ionized gases associated with the receptacle side of the circuit remain inside and those associated with the connector side of the circuit are dissipated on the outside.

The connector 50 is in a receptacle chamber 80 in the relatively high potential field associated with the cable conductor. This region would therefore be subject to corona problems unless all the air spaces around the receptacle were eliminated. This is accomplished by applying a conductive layer or member 81 to the inside wall of the chamber 80. If desired, the conductive layer 81 may be a conductive paint or coating.

The inside wall of the receptacle chamber 80 includes two peripheral members one (not shown) at the cable entrance end which serves to reduce the voltage gradient at the end of the conductive layer 81 because of the enlarged radius of curvature provided by the conductive surface of the grooves, and one 83 generally centrally of the receptacle chamber 80 which serves to lock the connector 50 in proper position in the chamber by means of a metallic spring ring 84. This ring 84 also serves to connect electrically the conductive layer 81 to the connector 50.

The outer surface of the hard dielectric filler 40 is also provided with a conductive layer or member, in the form of a conductive coating in the regions where it is normally in contact with the metal housing 34. This is to prevent ionization of air in the small gap between the inside surface of the housing 34 and the outside surface of the filler 40 which may occur due to differences in the thermal expansion coefficients of the two materials. This problem of differing thermal coefficients of expansions also occurs between the soft dielectric filler 38 and the metal housings 34 and retainer 39. However, in these locations the action of the latch springs 68 and the thrust spring 37 on the soft elastomer keeps all of the critical interfacial surfaces in void-free contact throughout the ranges of expected ambient temperatures and operating conditions.

The grounding cover 32 serves to provide a coupling for a cable termination 30 when it is desired to work in the area of a disconnected terminator. To this end, the coupling conductor 77 of the grounding cover is electrically connected to a metal grounding housing or cap 88 which in turn is grounded to the spring latches 66 and the conical skirt 65 to the grounded conducting housing 34 of the cable termination. However, an additional ground connection is recommended to the grounding cap housing by means of a flexible ground wire connected to the terminal 88*b*. A soft dielectric filler 90 fills the grounding cap around the coupling conductor 77 and forms a void-free interfacial engagement

with the conical sealing surface 41 of the cable terminal. As heretofore, described, the latch springs 68 serve to maintain a permanent void-free interfacial seal between the critical interfacial surfaces in a manner similar to the thrust spring 37. Thus, there is provided a conical sealing assembly with the hard dielectric filler 40 having a convex sealing surface 41, while the mating soft dielectric filler 90 has a concave mating surface 91, which, in the illustrated embodiment, are both conical in shape.

The structure shown in FIGS. 1, 2 and 3 is particularly adapted to receive the coaxial cable 45 which employs the plurality of wires 48 arranged in symmetrical spirals over the outside surface of the cable. These wires serve as the neutral conductor of the circuit as well as a grounded protective sheath. Since these wires 48 are part of the power circuit, they must provide a high conductivity path throughout the circuit. For this reason, the lower cover 35 is provided with extension members 92 which receive split bolt connectors 93 for holding the strands 48 of the neutral conductor so as to make connection and at the same time hold the cable firmly in place. The neutral wires 48 can then continue on to be grounded to ground or other neutral wires as hereinafter described. The extension member 92 also serves as means for rotating the cover 35 into the closed and latched position.

FIGS. 6, 7 and 8 illustrate a simple typical switch connection between two cable terminations of the type heretofore described. As therein illustrated, a pair of cable terminations identical to that heretofore described, are supported in spaced relation from a grounding rod 95 by a suitable mounting clamp 96. The mounting clamp 96 is precisely machined to match the diameter of the terminal housings 34 and includes members each having a groove 97 for accommodating a rib 98, FIGS. 1 and 2, which is precisely located on all of the housings 34. The mounting clamps 96 are provided with grooves or slots 97 so as to fit the rib 98 whereby all of the terminations 30 are rigidly held in place at the proper level with respect to the mounting clamp 96. Thus, all terminations 30 in a single mounting clamp will be normal to the plane of the bracket, at a standard distance apart and at a standard level permitting complete interchange of removable components.

As best illustrated in FIG. 6, the neutral wires 48 of the cables 45 are divided into two parts, one half going to one extension member 92 and the other half to the other extension member 92 of a respective termination 30. This is done in order to balance the forces holding the cable in place and also to keep all of the neutral wires tight and uniformly covering as much of the cable sheath as is possible. A grounding clamp 99 on the grounding rod 90 serves to join all neutral wires together and to connect them to ground.

The pair of cable terminations 30 in FIG. 6 are connected by a U-shaped switch coupler 100, also illustrated in FIGS. 7 and 8, and provided with a loop 101 for engagement with a lineman's hot stick. The switch coupler 100 includes a central conducting assembly made up of two switch couplings or pins 104 serving as switch blades and braised or otherwise secured to a crossbar 105 formed of electrically conducting material such as copper. The switch couplings are silverplated and carry a switch tip 104*a* which is dimensioned so as to fit the switch cavity 53*a* in the mating cable terminal. The horizontal portion of the central conducting member carries a cylindrical molding of conductive plastics or other suitable material 106 to enlarge the radius of the conductive portions and reduce the potential gradient. This cylindrical molding of conductive material 106 eliminates corona problems from air gaps in high gradient regions which could develop due to differences in thermal coefficients of expansion between plastics and metals. With this construction the field starts at the outer surface of the conductive material 106 which is surrounded in bonded, void-free relationship with a hard dielectric filler 107 of the same expansion coefficient as the conductive material 106 so as to remain sealed at all temperatures. The entire assembly is enclosed within a conductive housing here illustrated as a stainless steel housing 108, formed of mating housing portions 108*a* and 108*b*, so that the filler assembly including the contact plugs 104, crossbar 105, conductive material 106, and hard dielectric filler 107 may be prefabricated and then assembled within the housing. The housing portions 108*a* and 108*b* may be gripped in place together such as by the overlaps 108*c*. The housing 108 is closed by end caps 109 which may be spot welded into position.

The standardized conical sealing surface 41 of the cable terminal 30 must be mated with a soft dielectric in order to establish the void-free interface under the spring forces of the standard latch system. This is accomplished by providing conical cavities 110 around the switch coupling 104 in the dielectric filler 107 which are larger than the standardized conical sealing surface 41. A soft dielectric molding 111 is preformed with the exact geometry of the space between the conical cavities 110 and the conical sealing surfaces 41 to provide the standard conical sealing surface 91. The soft dielectric fillers 110 are formed of double cones bonded to the hard dielectric filler 107 on the coupler 100 to provide a permanent void-free interface between the hard and soft dielectrics in the coupler 100. Each of the downwardly

depending portions of the coupler housing is provided with a pair of latch springs 66 at the ends of latch loops 67 and adapted to be loaded through latch springs 68 in the manner described in embodiment of FIGS. 1, 2 and 3.

By the proper selection and arrangement of grounded surface elements, a variety of important distribution system functions can be performed. FIGS. 9, 10 and 11 illustrate, for example, an assembly 120 of standard elements arranged so as to provide a single fuse tap, illustrated in phantom at 114, on an underground distribution loop circuit. Sectionalizing functions are provided by means of two switch couplers 100 of the type illustrated in FIGS. 6 to 8. The necessary interconnections are established by means of a three terminal manifold or bus 115 and three cable terminations. Each cable termination 30 is identical with that of FIGS. 1, 2 and 3. In addition, the manifold 115, as illustrated, is provided with three vertical risers or cable terminations 116 each containing similar load-break features. Thus, each riser 116 is an exact replica in form and function as the upper end of the standard cable termination. Each riser housing includes a locating rib 117, FIG. 11, and latching cone 118 so that all removable components will interfit. Thus, one of the risers 116 and one of the cable terminations 30 are tied together by the mounting clamp 96 onto the grounding clamp 95. The remaining two vertical risers 116 and cable terminations 30 are connected by a 4-place mounting clamp 122 secured to a grounding rod 123. Each of the clamping portions of the mounting clamp 122 is provided with a circumferential groove 124, FIG. 10, receiving one of the locating ribs 98 and 117 to vertically position the respective terminations.

The design details of the manifold 115 will be more clearly understood by reference to FIG. 11. As therein illustrated, the manifold 115 includes a central conductor 128 which may be of copper or other suitable material. Standard switch connectors 50*b*, identical with the switch connectors 50*b* of the connector 30 illustrated in the embodiment of FIGS. 1, 2 and 3, are brazed to the central conductor 128. Briefly, therefore, the switch connectors 50*b* each include the switch receptacle 51*a* provided with the switch cavity 53*a* for receiving a mating connector rod. As heretofore described, the switch receptacle 51*a* is similar to the switch receptacle 51*a* illustrated in FIGS. 4 and 5 and include the plurality of fingers 62 encircled by the tension ring 63. The liner 72 of arc-quenching material leads into the switch cavity 53*a*, and the projectable follower 73 is biased into the liner 72 by the projection spring 74 when connecting components are not in place. It is understood that the load-break components including the sleeve 72, follower 73, and projecting spring 74 may be omitted where it is not desired to provide for breaking of the circuit under load.

In like manner as with the switch coupler 100 illustrated in FIGS. 7 and 8, a conductice material 130 is cast around the middle connecting circuit components thereby enlarging the radius of the conducting portion and reducing the potential gradient. Thus, there is eliminated the corona problems from air gaps in high gradient regions which could develop due to differences in thermal coefficients of expansion between the metal parts and the dielectric fillers. With this construction, the field starts at the outer surface of the conductive material 130. However, since the upper ends of the switch receptacle 51*a* in the region of the follower 73 must be movable, a soft cover 131 of plastics or other suitable material covers the free end of the switch receptacle 51*a*. A hard dielectric filler 132 is molded over the entire conducting system with the outside surfaces conforming to a housing 133 of stainless steel or other suitable material to a housing and with the standard conical sealing surface 41 of each riser position. The entire manifold assembly 115 may be preformed and inserted into an upper housing portion 133*a* with a lower housing portion 133*b* slipped into position and with end caps 134 spot welded into place. As in previous components, the outside surface of the hard dielectric filler 132 is covered with a conductive layer (not shown) except on the conical sealing surfaces.

The risers 116 may be provided in any number; however, most circuit requirements can be met with three or four termination manifolds. It should be noted that the risers are arranged in line and spaced the standard distance apart. Also, the vertical sleeve portions of the housing 133 are fully standardized to fit brackets and to mate with removable components. Thus. two four termination manifolds can be combined to provide sectionalized switches and four fused taps in a single control center.

Surge protection is frequently desired at the open end of a loop circuit or other suitable locations when it is to remain in this condition for a long period of time. FIG. 12 illustrates in partial cross section a surge arrestor 140 which may be connected to any of the standard treminations in a cluster or control center. The surge arrestor 140 includes a grounding housing 141 of stainless steel or other suitable material and includes a lower portion 141*a* which is standardized with the conical sealing surface 91 to the fit cable terminations and manifolds of the grounded surface distribution system. The functional parts of the surge arrestor 140 include a system of quench gaps 142 in series with valve blocks 143 of suitable material

such as silicon carbide. These elements are arranged in a dielectric tube 144 under compression of a compression spring 145. The housing includes a top cover 146 locked to the remainder of the housing through side pins in like manner as cover 35 in the embodiment of FIGS. 1, 2 and 3. The space between the dielectric tube 144 and the metal housing 141 is filled with a soft dielectric filler 147 which is maintained in void-free interfacial contact by means of the inner thrust spring 37 acting between the end cover 146 and the retainer 39. A connector pin 148 extends from the lower end of the surge arrestor 140 for mating within the switch cavity 53*a* of a collaborating member. A cone of soft dielectric material 149 is placed around the upper end of the contact plug 148 in order to control the gradient in this region. It is understood that the connecting components of the lower housing 141*a* are identical to those heretofore described, including the spring latches 66, the latch loops 67, and the latch springs 68 which serve the dual function of biasing the spring latches 66 and applying a positive pressure to the dielectric filler 147.

To provide for fusing of the grounded surface distribution system, one of the interchangeable elements may consist of a current limiting fuse, such as the current limiting fuse 152, as illustrated in FIG. 14. As therein illustrated, the current limiting fuse 152 is housed within an assembly similar to the switch coupler 100 more fully described in the discussion of FIGS. 7 and 8. More specifically, there is provided the fuse unit 153 enclosed within a metal housing 154, similar to housing 108 heretofore described, and cast in the center of a hard dielectric filler 155. A pair of conically shaped soft dielectric fillers 156 are provided having the standard conical sealing surfaces 91 for engaging the conical sealing surface 41 of cable terminations or manifolds, and the fuse 152 is provided with the standardized latches to interfit with the the other components.

Referring now to the fuse unit 153, the operation thereof is known and depends upon the melting and vaporization of a silver fuse wire 157 and the subsequent deposition of the silver over the surfaces of sand grains 158 which surround it. This takes place so rapidly under high fault conditions that the current is cut off before it reaches the full value of the available fault current. The silver metal becomes so diffused in the sand grain matrix that it no longer carries significant current. In such fuses it is necessary to maintain sufficient distance between the turns of the silver wire to prevent hot ionized gas from shorting out turns. In the illustrated design, in order to minimize the length of the fuse for a given rating, a wide flange surrounding the spiral core 159 is used to separate the turns of the silver fuse wire 157. As previously mentioned, this space around the wire between the spiral flanges is filled with refractory granules such as alumina or silica. The granular matrix may be bonded with a minimum of refractory cement in order to permit the assembly of the parts within an insulating tube 160. The tube 160 may be of organic or inorganic material, but preferably it is of high strength and refractory at least in its lining in order to minimize internal pressures which may develop during operation. This fuse has no outlet for gaseous discharge since its entire envelope must be capable of withstanding system voltages within the grounded housing. The respective ends of the silver fuse wire 157 are soldered to the center of opposed cylindrical ferrules 161 fitted over the ends of the surrounding spirals 159 and insulating tube 160. A pair of contact rods or plugs 162 extend coaxially through their respective soft dielectric fillers 156 for engagement within plug receiving cavities 153 of a conductor assembly 50.

In order to control the potential gradient around the turns of the fuse wire in the sand and thus prevent corona in this region, a conductive film is applied to the outer surface of the fuse tube 160. A termination to terminal resistance in the range of 50 to 150 megohms provides satisfactory operation of the fuse.

In the above fuse design, the active fuse wire 157 is not removable in the field from the matrix of the hard dielectric filler 155. When blown, the fuse 152 will have some salvage value for factory rebuilding, but cannot be rebuilt in the field. FIGS. 15 and 16 illustrate a current limiting fuse 165 which, although somewhat more expensive initially than the fuse 152, may have the active element replaced by the user in the field, and the fuse unit 165 could go back into service immediately.

The principle of operation of the fuse 165 is similar to that of fuse 152 and includes the silver fuse wire 157 between the flanges of the spiral core 159 filled with suitable refractory granulars or sand grains 158. This active fuse element is housed within removable fuse cartridge 166 which can be removed from a metal housing 167 for replacement by releasing one or both of a pair of opposed end thrust spring covers 168 and unscrewing a pair of contact rods or plugs 169 from plug blocks 170. In the fuse 165, the entire space between the housing 167 and the fuse tube 166 is filled with soft dielectric filler 171 and is maintained in void-free contact by end thrust springs 172 interposed between the spring covers 168 and respective retainer cups 173. A bayonet connection joins the spring covers 168 with the housing 167 in a manner similar to that illustrated in the embodiment of FIGS. 1, 2 and 3. The conical

sealing surface 91 is maintained on the soft dielectric to engage the conical sealing surface 41 of a cable terminal, manifold riser or the like. The conical sealing surfaces are maintained in void-free contact by the latching system heretofore described including the spring latches 66, latch loops 67, and latch springs.

The grounded surface distribution system according to the present invention is versatile and permits numerous combinations of standard elements to provide a variety of circuit control centers. There is illustrated in FIGS. 17 to 20 a two-level tap arrangement for a control center which permits some reduction in space and in the number of components required. However, these components are not fully interchangeable with the previously described standard components. As therein illustrated, for example, there is shown a switching or control center wherein a tap 178 is taken from a main line 179, 180. Each of the lines and the tap, 178, 179 and 180 includes a respective cable 181, 182, 183 terminating in the cable terminations 30 similar to that described in the embodiment in FIGS. 1, 2 and 3. Each of the cable terminations 30 is supported by a three way mounting clamp 184 from a grounding rod 185. Each of the cables 181, 182 and 183 is of the grounded surface type having the plurality of strands 48 of grounding wire which are first secured to the extension members 92 on the respective cable terminations 30, and are run through a ground clamp grounded to the grounding rod 185 in the manner previously described. The cable terminations 30 associated with the line 179, 180 is supported at the same vertical level; however, to provide the multi-level tap, the tap assembly 178 is supported at a higher elevation. To this end the housing of the cable terminations 30 may be provided with suitable locating means such as a detent or the like.

To provide suitable control functions, there may be provided a line fuse 190 of the current limiting type and interconnecting the line assemblies 179 and 180 in a conventional manner. However, additionally the line fuse 190 is provided with an upwardly extending standard conical sealing portion 191 having the standard conical sealing surface 41 and defining a tap from the line 179, 180.

To provide for connection of the tap 178, there may be provided a tap fuse 192, similar to that heretofore described, but having one of its standard sealing portions longer than the other joining between the cable terminations 30 of the tap 178 and the sealing portion 191 of the line fuse 190. Thus, there is provided a switching center wherein either line 179—180 of a loop may be isolated, or alternatively the tap 178 may be isolated. Isolation of one line 179 is illustrated in FIGS. 19 and 20. In this embodiment the line fuse 190 has been removed, and the tap fuse 192 has now been connected between the tap 178 and the line 180. In addition, the grounding cover 32 is shown on the isolated line 179. An isolating cover also may, if desired, be applied to this component.

The tap can also be connected directly to the terminal of a component by using an L-shaped coupler 200 illustrated in FIG. 21. As therein illustrated, the L-coupler 200 is connected directly to a terminal 201 of an electrical apparatus fragmentarily illustrated at 202. The terminal 201 includes the connector assembly with the switch connector *50b* cast within a hard dielectric 203, and similar to the switch connector *50b* of the connector 50 more fully described in the embodiment of FIGS. 1 through 3. However, briefly, the switch connector *53a* includes the socket member *51a* provided with a plurality of fingers 62 biased together by the tension ring 63. The follower 73 will project through the liner 72 under the force of the compression spring 74 to provide the arc-extinguishing feature of the terminal. The terminal 201, of course, is provided with the standard conical sealing surface 41 and the conical skirt 65 to provide latching thereto.

The L-coupler 200 includes a conducting housing 204 enclosing a cable connector *50a*, similar to that described in the embodiment of FIGS. 1, 2 and 3. Briefly, the cable connector *50a* includes the receptacle 51 having a plurality of fingers 62 biased together by the tension ring 63 and defining the pin cavity 53. The pin 52 is secured to the end of the tap cable 45 and is received within the pin cavity 53 to provide the connection between the cable 45 and the cable connector *50a*. The coupling connector 77 extends from the cable connector *50a* at right angles thereto. The entire connector cable and cable 45 is encased within a soft dielctric *204a* held under compression to provide void-free interfacial engagement by means of the thrust spring 37 interposed between the cover 35 and the cup retainer 39. The coupling conductor 77 is receivable in the pin cavity 53 of the cable connector *50a* in the terminal 201. The soft dielectric is provided with the standard conical sealing surface 91 engageable in void-free relationship with the conical sealing surface 41 by means of the standard latches and springs.

Although the L-coupler 200 could be used in a switch center or cluster of cable terminations 30, it has particular usefulness as connection to such electrical apparatus as transformers and circuit breakers. Moreover, it is noted that only in the case of the L-coupler 200, the line cable 45 remains with the removable switching component.

It is of course, necessary to provide for cable splicing or joining and to this end

there is provided a cable splice 210 illustrated in FIGS. 22 to 24. The two ends of the cable splice 210 are identical, and accordingly, only one is illustrated and described in detail as shown in broken away cross section. The splice includes a conducting housing 211 of stainless steel or other suitable material and including at both ends the covers 35, each of which engages the two side pins 36 in a spiral bayonet action permitting the inner thrust spring 37 to be compressed in the latched position as shown so as to exert an axial thrust on a soft dielectric filler 212 by exertion of load against the cup retainer 39. The soft dielectric filler 212 is designed to receive the ends of a power cable 213, 214 similar to the cable 45 heretofore described. The end thrust springs 37 permit a reasonable range in diameter variation and still maintain a very permanent void-free interfacial seal between the insulation 213 and the soft dielectric filler 212.

Encased within the soft dielectric filler 212 is a coupling 215 including two opposed cable connectors 50*a*, each identical to the cable connectors 50*a* illustrated in FIGS. 1, 2 and 3. Briefly, each cable connector 50*a* includes a receptacle 51 and a pin 52, which pin 52 is secured to the conductor in the cables 213 and 214, respectively. The receptacle 51 defines a pin cavity 53 formed by a plurality of fingers 62 and held with an inwardly bias by the tension ring 63. The operative components of the coupling 215 are housing within a conductive cylinder 216 which serves the same function as the conductive layer 81 in the embodiment of FIGS. 1, 2 and 3, and which further serves to isolate the movable portions of the coupling assembly 215 from the soft dielectric filler 212. It will be recognized that the operative components for the cable connector 50*a* are identical to those illustrated in FIGS. 4 and 5.

To provide the continuous grounded surface of the system, the cables 213 and 214 are each covered with the grounding strands 48 of wire and which are secured to the extension members 92 of the respective covers 35 by the split bolt connectors 93 thus maintaining a continuation of the grounding conditions.

FIGS. 25 and 26 illustrate an embodiment of a circuit control center or switching center arranged similarly to that illustrated in FIGS. 17 through 19, but employing a modified T-tap termination for the terminations of the loop cables. As therein illustrated, there is provided a T-tap termination 220 for terminating ends of the loop cables 221 and 222, respectively. The T-tap termination 220 includes a pair of cable connectors (not shown), each similar to cable connector 50*a* described in the embodiment of FIGS. 1 to 3, for receiving pins connected to the end of the associated cable. The assembly is encased in the soft dielectric filler and held under compression by the described thrust spring acting between the retainer and the cover. A central bus interconnects the cable connectors associated with the respective cables 221 and 222 within a grounded housing 223. Moreover, a central tap or riser 224 extends from the T-tap termination 20 and includes a switch connector such as that illustrated as 50*b* in FIGS. 1 through 3. The riser 224 terminates in a standard conical sealing surface so as to join with the switch coupler 100 heretofore described.

A tap line 225 is provided with a standard cable termination 30 so that the switch coupler 100 joins in the manner heretofore described between the riser 224 and the termination 30. The termination 30 and the T-tap termination 220 are held in the proper space and vertical relationship by a mounting clamp 226 secured to a grounding rod 227.

Although the T-tap termination 220 is not fully interchangeable with other components of the system, its simplicity of construction and its single unit assembly make it desirable in some installations.

FIG. 27 illustrates a typical switching center or control center wherein the components are positioned within a well casing 230 below the surface of the earth 231. As therein illustrated, there is provided a plurality of cable terminations 30 and a plurality of multitap manifolds 115, each of the terminals 30 and manifolds 115 terminating in the standardized conical sealing surfaces. Suitable functional components, such as the illustrated switch couplers 100, connect the manifolds and cable terminations in the desired manner to provide the loop, sectionalizing or other desired function. The switch couplers 100 may be removed from the switching center by a standard hot line tool hooked through the loop 101 of the component. Switching couplers 100 removed from the switching center may be set aside, such as illustrated in FIG. 27, to provide a visual isolation of the respective lines. It is understood that a grounding cap, surge arrestor, or other suitable component may be placed over the terminals or manifold risers after the switch coupler has been removed therefrom.

From the above description, it is seen that there is provided an improved grounded-surface distribution system wherein the entire electrical structure is enclosed in metal housings thick enough to provide mechanical support and to carry fault current if it occurs. The entire high potential conductor system has been placed inside of these grounded housings with adequate coupling and transition means for carrying out switching and sealing functions. A void-free elastomer or soft dielectric surrounds the high voltage elements with compression springs at appropriate locations to maintain all critical inter-

faces void-free and under pressure at all ambient variations expected in the field. Each circuit is maintained separately in its own grounded sheath with interfitting components available to set up various functions such as switching or load-break disconnect. In this simple case the two cable terminations are clamped into a rigid two-way bracket mounted on a ground rod. The switching feature is present in both cable terminations independent of each other. The switch blade is a grounded surface inverted "U" which can be removed with a hot stick from above. The operator moves only the coupling piece. The cables or terminations are not moved or distributed in operation. The hot circuits are never exposed since the followers fill the connector openings when the switch is open. The open circuits are visually separated and metallic grounds are between them. Insulating or grounding caps may be securely latched over the elements of the open switch. Thus, the switch may be open with separate caps or closed with the "U" coupling and completely safe without hazard to operating personnel working in close proximity to them. An important feature of this system resides in the double load break which is always present since each cable termination contains an arc-quenching system which separates both sides of the high voltage circuit simultaneously from the removable coupler element. This insures more effective load break function and greater safety to the operator and requires no movement of the energized cables except in the single embodiment of the L-coupler illustrated in FIG. 21.

In our Patent Specification No. 1242068 (Application No. 31485/68) there is disclosed a cable termination for underground distribution systems comprising a cylindrical conductive grounding housing open at one end, a hard dielectric filler secured in the housing and having a convex sealing surface projecting in the direction of the open end, a readily removable conductive coupling element for the open end conductively engaging the housing, means for grounding the coupling element, a soft dielectric filler in the coupling element having a concave sealing surface making void-free interfacial engagement with the convex surface, and compression means associated with the coupling element to maintain the soft dielectric filler under pressure.

Also in our Patent Specification No. 1242070 (Application No. 6165/71) there is disclosed an electrical connector for a high potential grounded sheathed cable for underground distribution systems comprising, a first insulating member including a hard dielectric member provided with a frusto-conical sealing surface and enclosing a cable connector having a first electrically conductive contact member, and L-shaped or cranked second insulating member having a connection inlet comprising a soft dielectric filler with an inner sealing frusto-conical surface conforming to the first-mentioned frusto-conical sealing surface to produce a void free seal upon engagement of the surfaces, a second electrically conductive contact member in the inlet for engagement with the first electrically conductive contact member on engagement of the surfaces, a shield of low electrical resistance covering at least a portion of the outer surface of the second insulating member, and means for connecting the shield to the grounded sheath of a cable.

WHAT WE CLAIM IS:—

1. A control unit for high voltage electric power cable terminations of the type having first and second cable terminations with respective end surfaces, the unit comprising a conductive housing releasably positioned between the respective end surfaces of the first and second terminations, insulated electrically conductive means and a current limiting fuse in the housing, means for electrically connecting respective conductor terminals within the cable terminations to the conductive means whereby a current carrying circuit is completed between the terminals through the fuse, and means for forming water-tight uniform seals between the ends of the housing and the respective terminations when the current carrying circuit is completed, the current limiting fuse providing for the interruption of the current carrying circuit between the terminals.

2. A unit as claimed in claim 1, wherein the fuse comprises a cartridge-type fuse that is removably mounted in the housing.

3. A control unit substantially as described with reference to Figures 14 or 15 and 16 or Figures 17 and 18 of the accompanying drawings.

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Sheet 1

FIG.1.

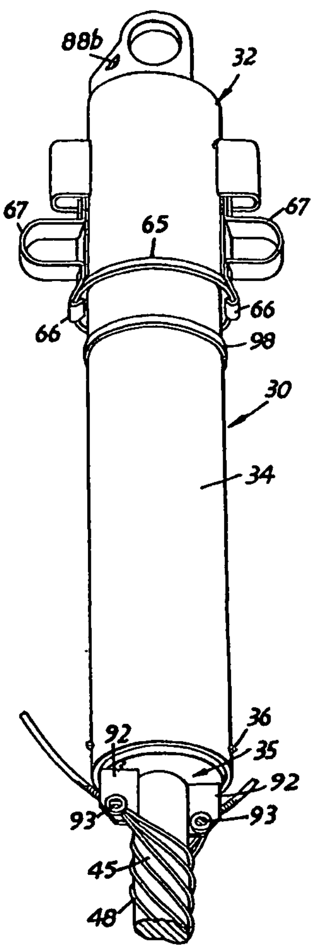

FIG.2.

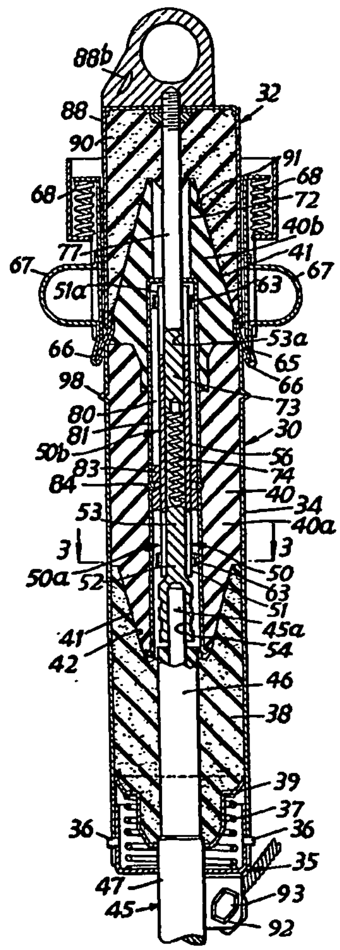

FIG. 3.

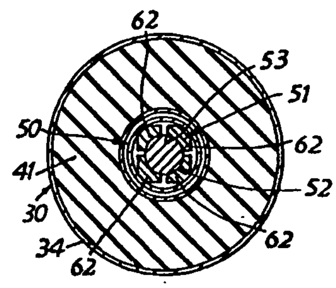

FIG. 4.

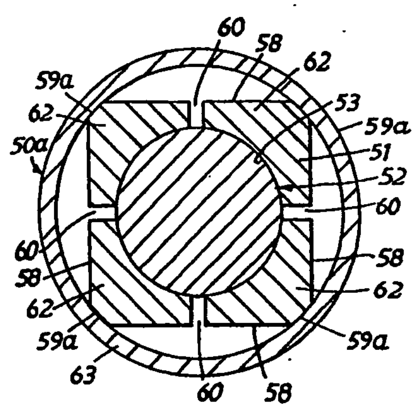

FIG. 5.

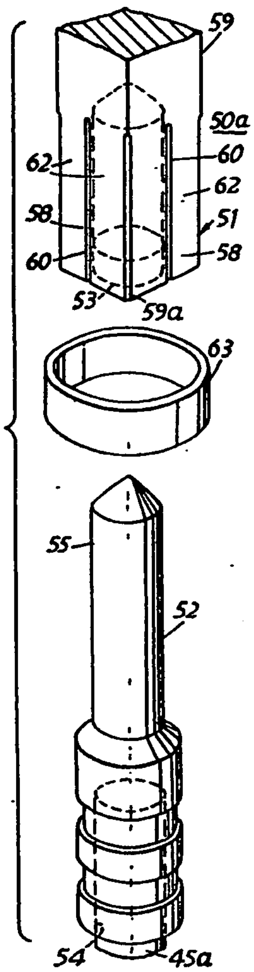

FIG. 6.

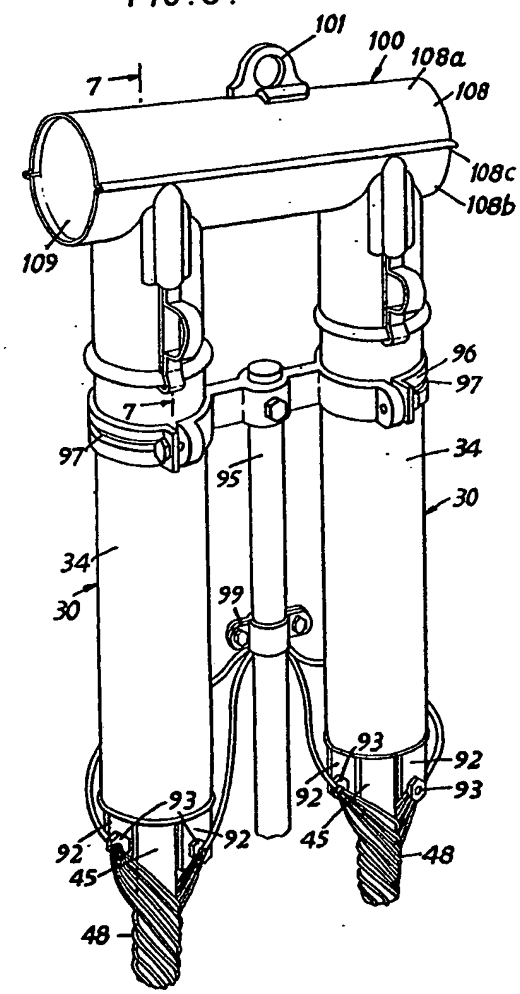
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FIG. 7.

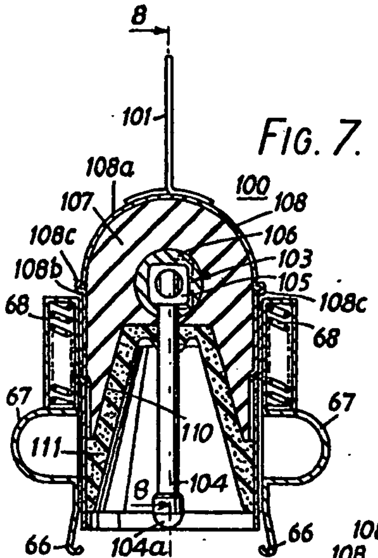

FIG. 8.

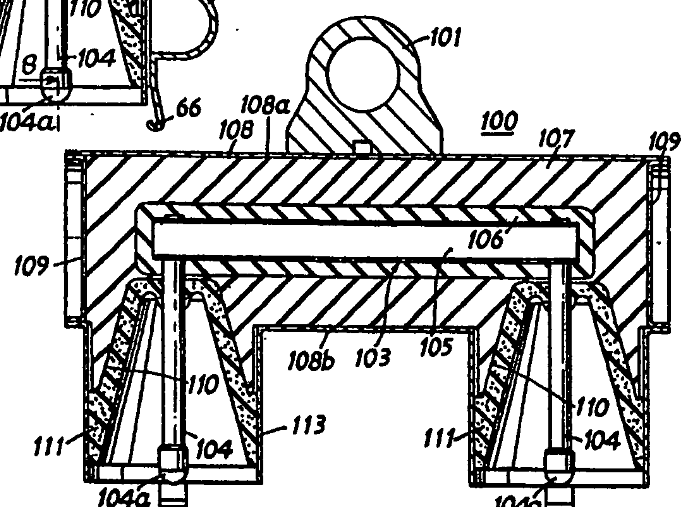

FIG. 9.

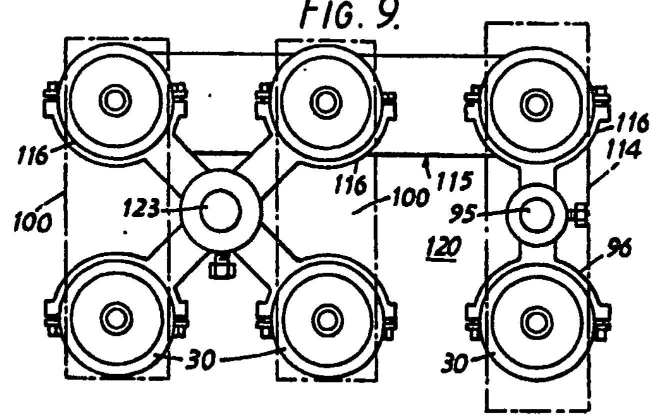

FIG.10.

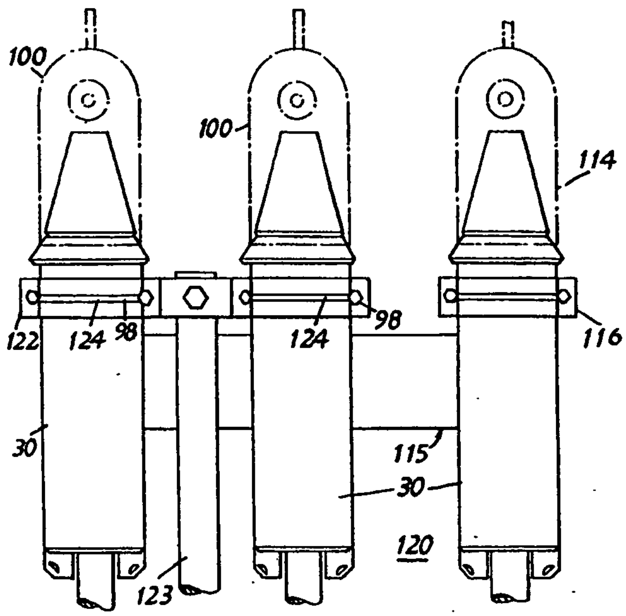
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FIG.11.

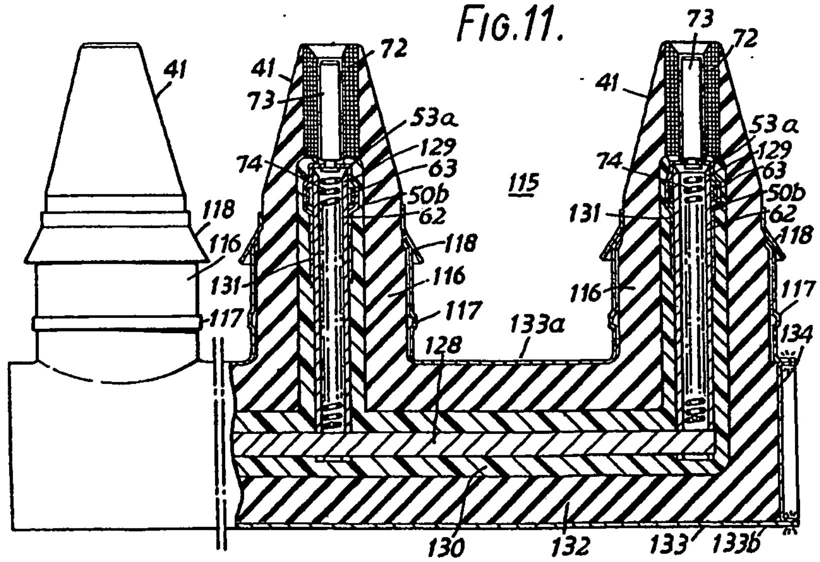
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FIG. 12.

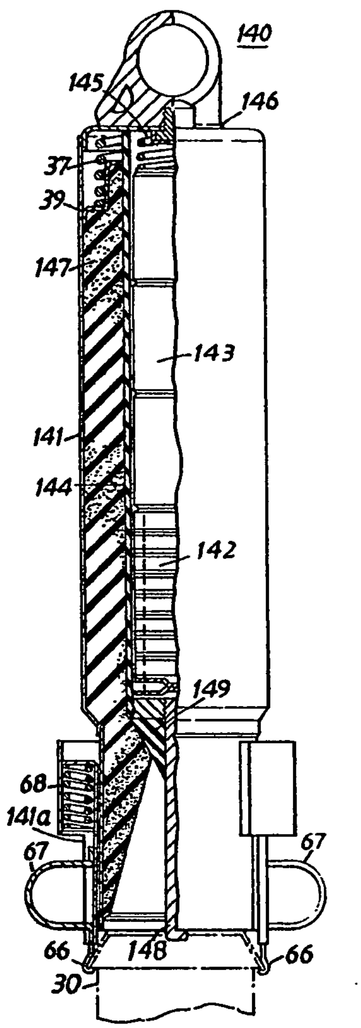
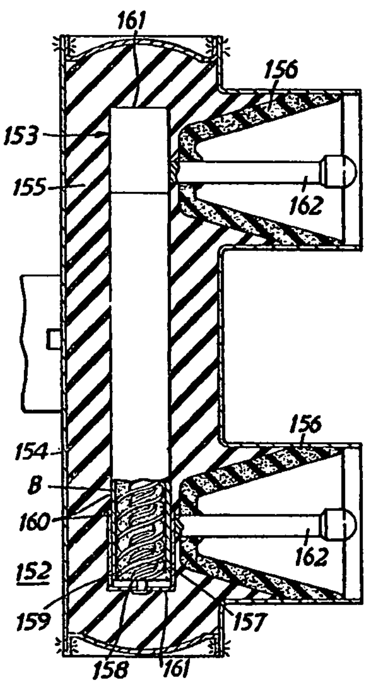


FIG. 14.



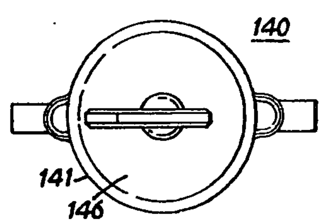


FIG. 13.

FIG. 15.

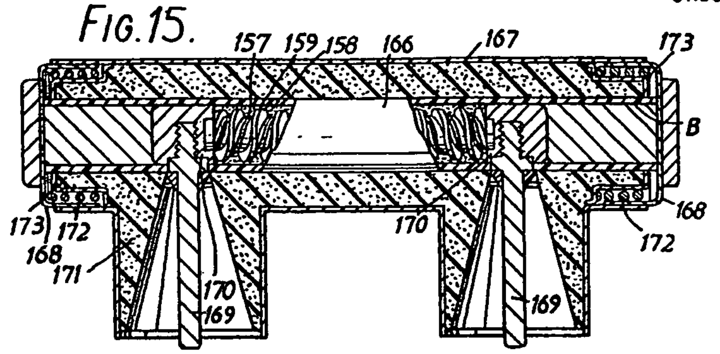


FIG. 21.

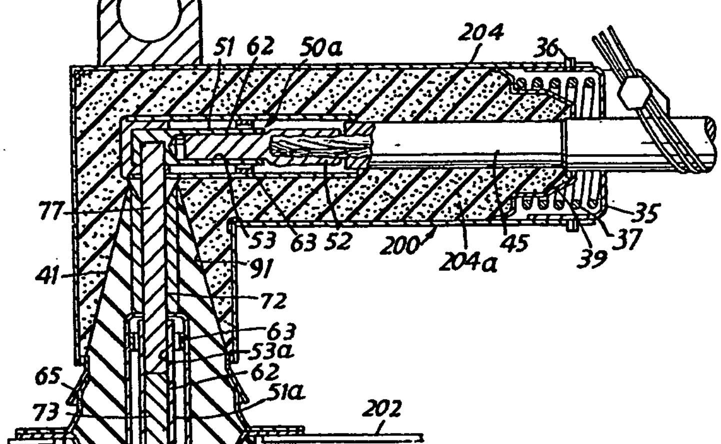
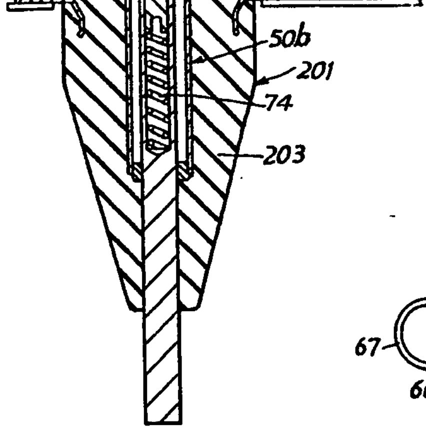



FIG. 16.

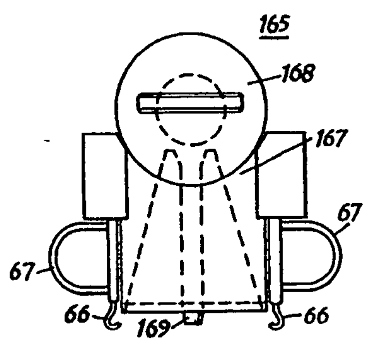


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FIG. 17.

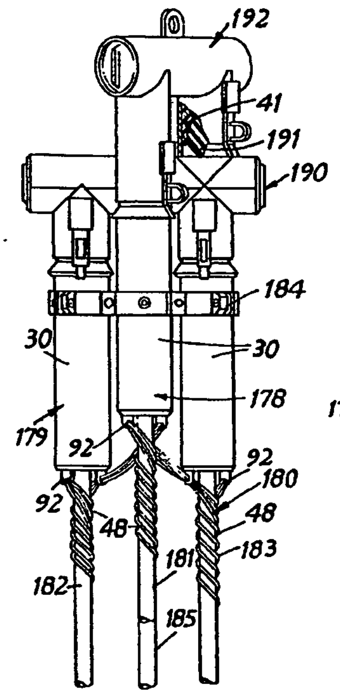

FIG. 19.

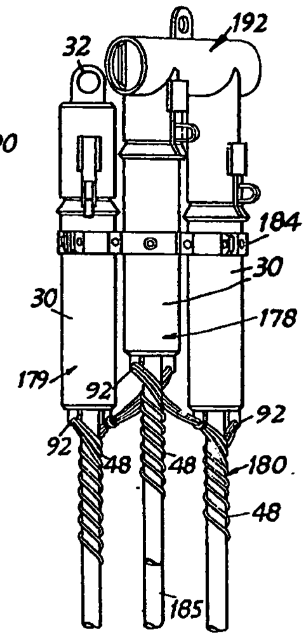

FIG. 18.

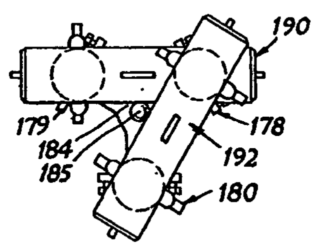

FIG. 20.

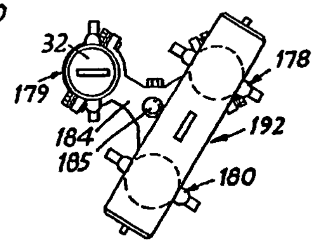

FIG. 22.

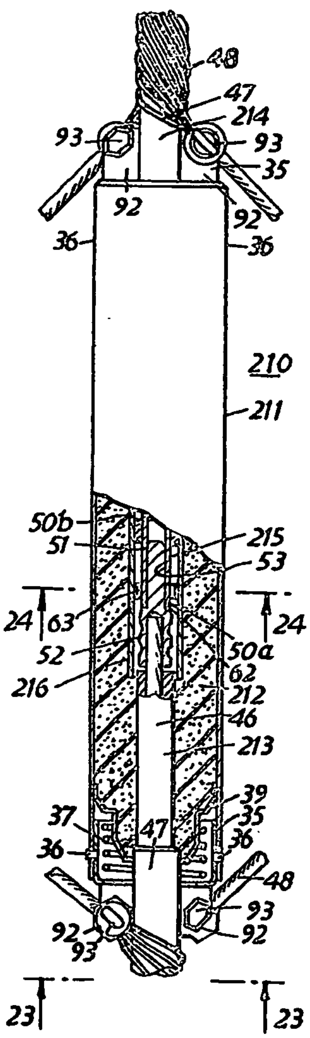

FIG. 23.

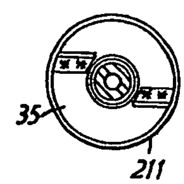

FIG. 24.

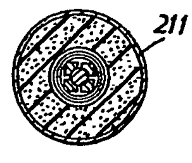

FIG. 26.

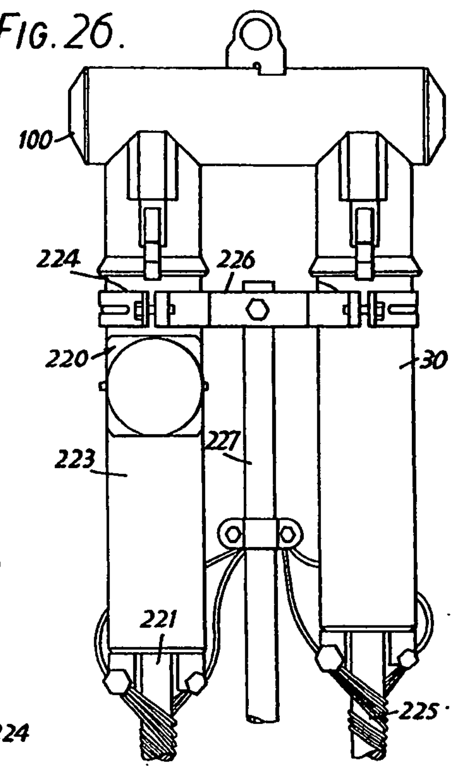
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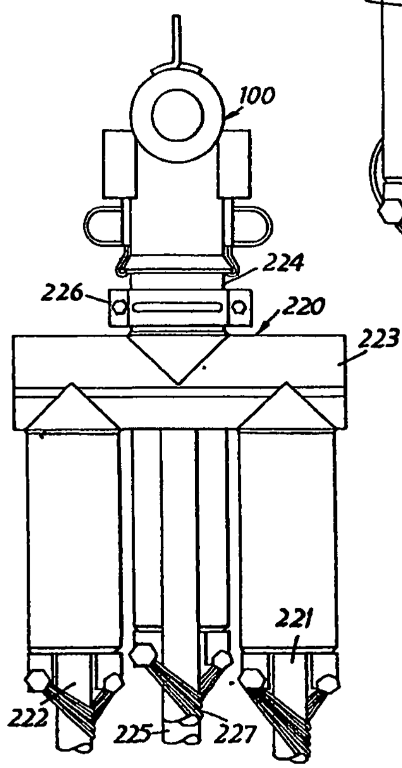
FIG. 25.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Sheet 11

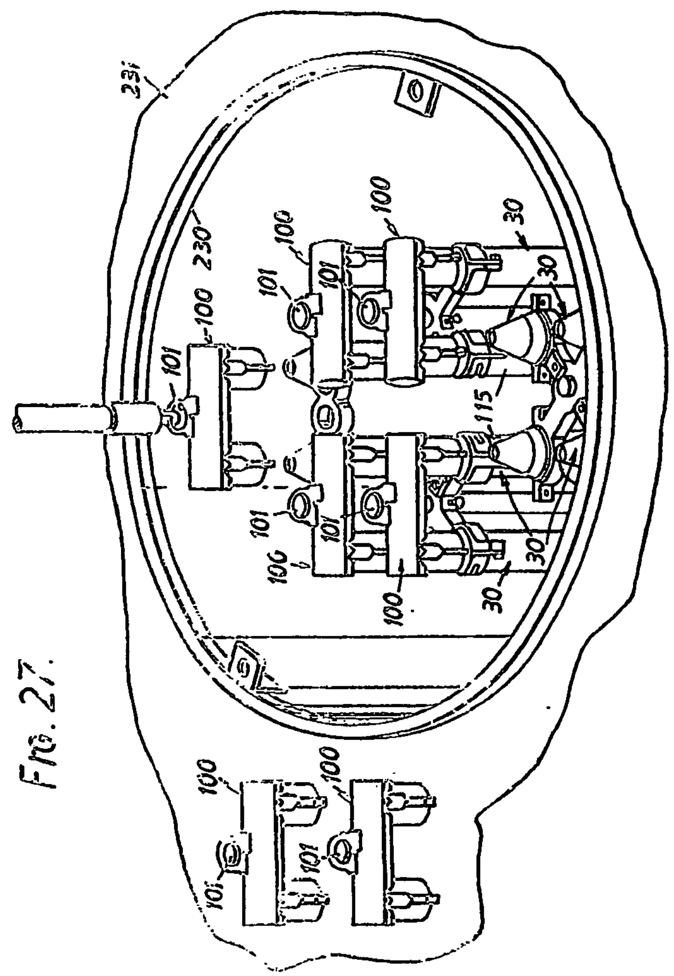

FIG. 27.